RESEARCH DEPARTMENT

Transmitting aerials for the Ashkirk television and v.h.f. sound station

REPORT No. E-087

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

TRANSMITTING AERIALS FOR THE ASHKIRK TELEVISION AND V.H.F. SOUND STATION

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SUMMARY

The design of the Band I and Band II transmitting aerials for the Ashkirk station has been based on theoretical predictions and model measurements which are described in this report. The aerials are mounted on a 750 ft (228 m) stayed mast of 4 ft (1·22 m) square cross-section.

1. INTRODUCTION

The Ashkirk television and v.h.f./f.m. sound relay station is sited at Dryden Hill, approximately 3 miles (4·8 km) due south of Selkirk. It is intended to improve reception in those parts of Berwick and Selkirk which are inadequately served by Kirk o'Shotts and Pontop Pike.

The Band I aerial at this station is designed for Channel 1, with vertical polarization; four translator-amplifiers, each giving an output power of 500 W, provide the vision signal. The v.h.f./f.m. aerial is designed for carrier frequencies of 89·1 (Light Programme), 91·3 (Third Programme) and 93·5 Mc/s (Scottish Home Programme); two 1 kW translator-amplifiers are used for each programme.

2. MAST STRUCTURE AND AERIAL ARRANGEMENT

2.1. Mast

The aerials are mounted on a stayed mast of square cross-section 4 ft × 4 ft (1·22 m × 1·22 m) having an overall height of 750 ft (228 m) and oriented with one stay on a bearing of 53° ETN. Provision has been made for the addition of a 60 ft (18·3 m) cantilever topmast, should this be required for a u.h.f. transmitting aerial; with the addition of this topmast the total height of the structure will be 810 ft (246 m). The mast is screened over the radiating lengths by a 6 ft 9 in (2·06 m) diameter steel cylinder.

2.2. Aerial Arrangement

Fig. 1 shows the general arrangement of aerials on the mast.

2.2.1. Band I Aerial

The aerial consists of two similar halves each consisting of four tiers of vertical dipoles, with an inter-tier spacing of $1 \cdot 03\lambda$. The mid-points of the two halves are separated by 120 ft (36·6 m) i.e. $5 \cdot 5\lambda$, and the mean height of the complete aerial is 625 ft (191 m) above ground level.

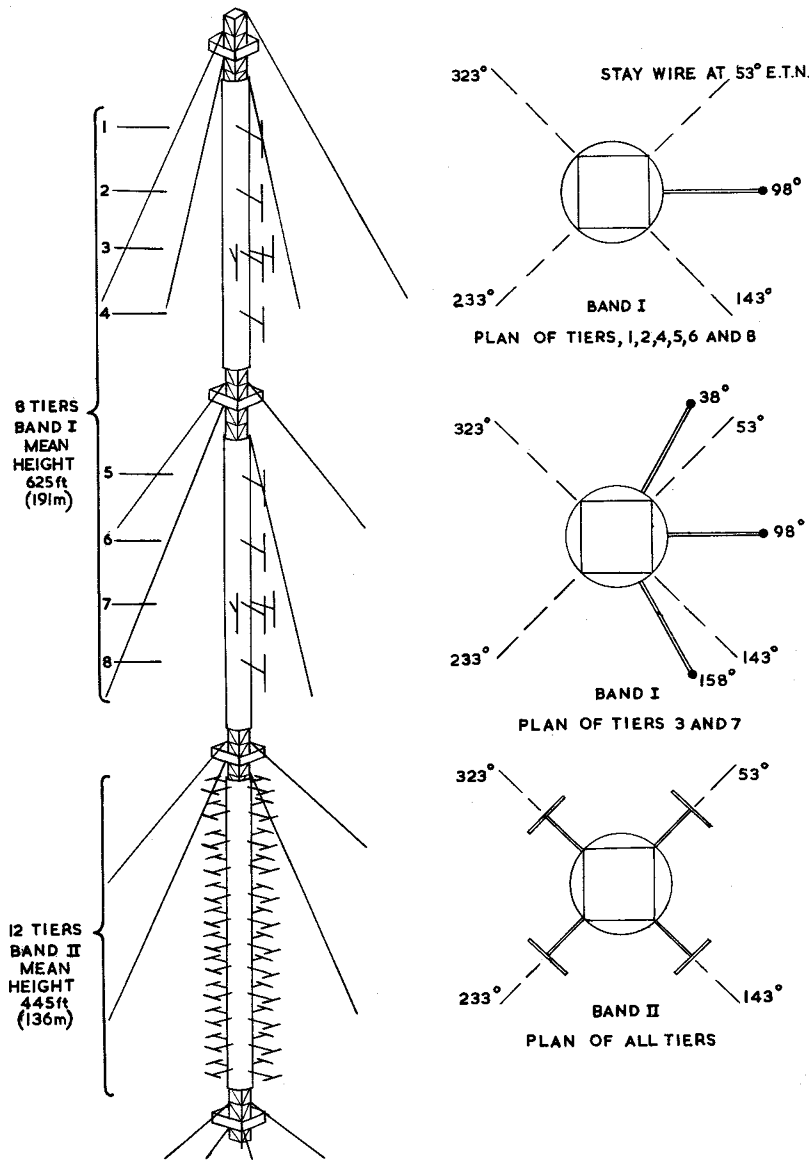

Fig. 1 - General arrangement of aerials on mast

All tiers have a dipole at a bearing of 98° ETN; tiers 3 and 7 are provided with additional dipoles at bearings of 38° and 158° ETN. All dipoles are spaced 10 ft 6 in (3·2 m) i.e. $0 \cdot 48\lambda$ from the mast axis, and are fed with equal co-phased currents.

2.2.2. Band II Aerial

The aerial consists of twelve tiers of tangential dipoles with an inter-tier spacing of 0·7λ and a mean height of 445 ft (136 m) above ground level.

All tiers have dipoles spaced 6 ft (1·83 m) i.e. 0·55λ from the mast axis, at bearings of 143°, 233° and 323° ETN, each fed with unit current, and one dipole spaced 5 ft 9½ in (1·76 m) i.e. 0·53λ from the mast axis at a bearing of 53° ETN, fed with two units of current; all currents are co-phased.

3. HORIZONTAL RADIATION PATTERNS

3.1. Band I Aerial

The horizontal radiation pattern (h.r.p.) of the Band I aerial was required to satisfy the templet shown in Fig. 2. The preliminary design was based on a h.r.p. calculated on an analogue computer[1] using tables of complex h.r.p.s of dipoles

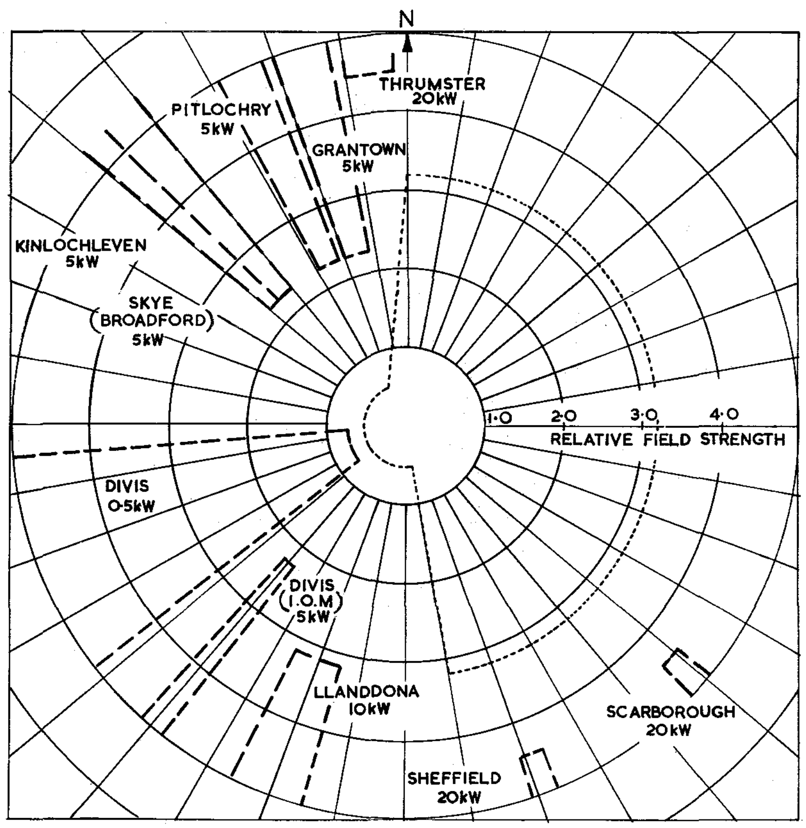

Fig. 2 - Templet for Band I aerial

Channel 1
Vertical polarization
Vision and sound carrier offsets: +16·875 kc/s
—— —— Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 1 kW

mounted on a cylinder.[2] The theoretical performance of the equivalent single tier of the system is shown in relation to the templet in Fig. 3. The theoretical h.r.p. does not include the effect of re-radiation from the mast stay wires; this effect is not readily amenable to calculation, and for this reason it was necessary to carry out model measurements to determine the precise h.r.p.

The proposed aerial comprised similar (rather than mirror-image) halves, each with a stay-attachment point at the same relative position. The h.r.p. of the lower aerial would therefore be affected by two sets of stays, but it was considered that the effect of the outer compared with the inner stay wires would be small. It was further considered that measurements on a model of the upper half-aerial would indicate to a sufficient accuracy the performance of the complete aerial. Accordingly, a model of one half of the aerial was constructed to a scale factor of 10·4 : 1 (corresponding with an operating frequency of 467 Mc/s). Since the aerial is vertically polarized the h.r.p. is not dependent on the precise form of dipole and is unaffected by re-radiation from the horizontal support booms; exact replicas of the full-scale dipoles were not therefore required, and simple thin-tube dipoles were used.

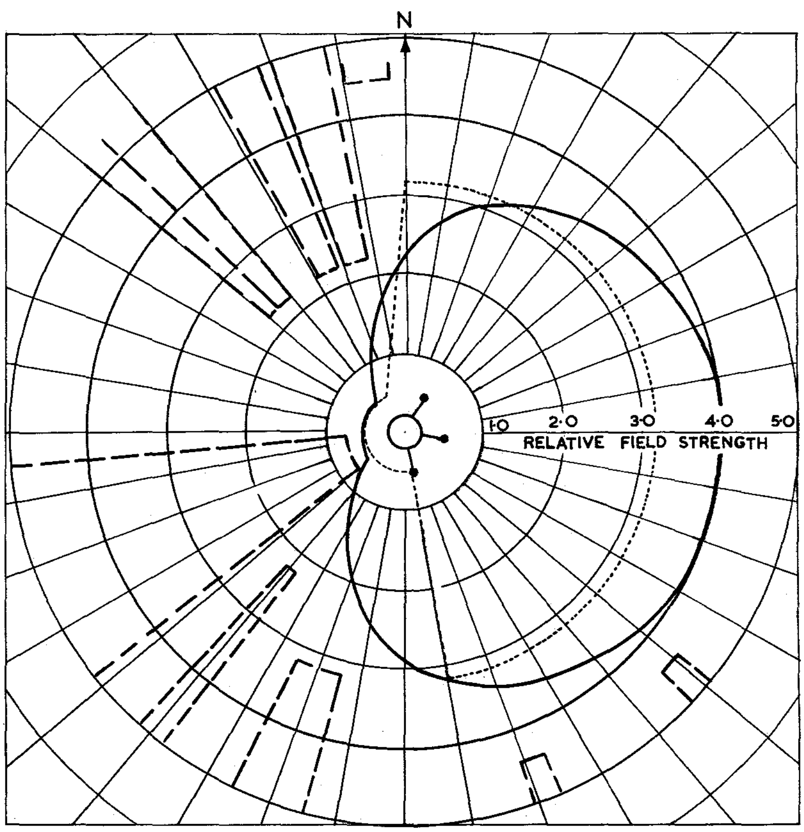

Fig. 3 - Theoretical horizontal radiation pattern of Band I aerial

Channel 1
Vertical polarization
Mean effective gain: 5·5 dB
Transmitter power: 4 × 0·5 kW
Mean e.r.p.: 7·1 kW

Vision and sound carrier offsets: +16·875 kc/s
—— Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 1 kW

The model dipoles were fed from a common point through equal lengths of cable, accurately cut to be an odd number of quarter-wavelengths. The dipole currents thus established were measured by means of an impedance perturbation technique.[3] In order to adjust the dipole currents to equality in amplitude and phase it was found necessary to shorten the distribution feeders by $0{\cdot}062\lambda$; the ratios finally obtained were assessed to be correct within ± 3% in amplitude and ± 4° in phase.

The large overall size of the model aerial made it necessary to take particular care over the arrangements for measuring the h.r.p., in order to obtain a sufficiently uniform illumination over the whole length of the aerial. For this purpose a special fixed aerial was developed, and by using a particular relative disposition of this aerial and the model aerial under test the effects of reflexions from the ground were substantially eliminated. With this arrangement the measured field over the length of the four-tier model aerial showed amplitude variations of less than ± 0·25 dB; this degree of uniformity was considered to be satisfactory.

The measured h.r.p. of the model without stay wires was in good agreement with that predicted theoretically. The effect of stays on the h.r.p. was found to be appreciable but this did not vary significantly over a range of stay angles likely to obtain in practice. Fig. 4 shows that the measured h.r.p. in the presence of stays is still a reasonable fit to the templet.

The change of h.r.p. over the frequency band was assessed theoretically and was found to be significant only in the region of the minimum of the h.r.p. at a bearing of 270° ETN. Comparing h.r.p.s at the vision carrier frequency, f_v Mc/s, and at the extreme sideband of the vision transmission (f_v-3) Mc/s, it was found that the e.r.p. over the arc 240° to 300° ETN varied by up to 1·2 dB. Since a limit not exceeding ± 3 dB was regarded as reasonable for the overall change of response at (f_v-3) Mc/s relative to that at f_v, it follows that to meet the requirement the element radiating currents must be maintained to within close limits over the band (see Section 3.2.).

3.2. Dipole Currents of Full-Scale Aerial

It is not practicable directly to measure the h.r.p. of the full-scale Band I aerial, and it was therefore considered necessary to measure the radiating currents in the aerial elements, and also to specify the accuracy to which the currents should be established. The permissible departure from the condition of equal co-phased currents was estimated as follows:

Using the theoretical h.r.p. shown in Fig. 3, the effect of an incorrect current ratio between the element at 98° ETN and those at 38° and 158° ETN was calculated. (The elements at 38° and 158° are presumed to have equal currents on grounds of symmetry.) Four cases were considered:

(a) a variation in the amplitude ratio of ± 20%, the phase remaining correct;

(b) a variation in the relative phase of ± 10°, the amplitude ratio remaining correct.

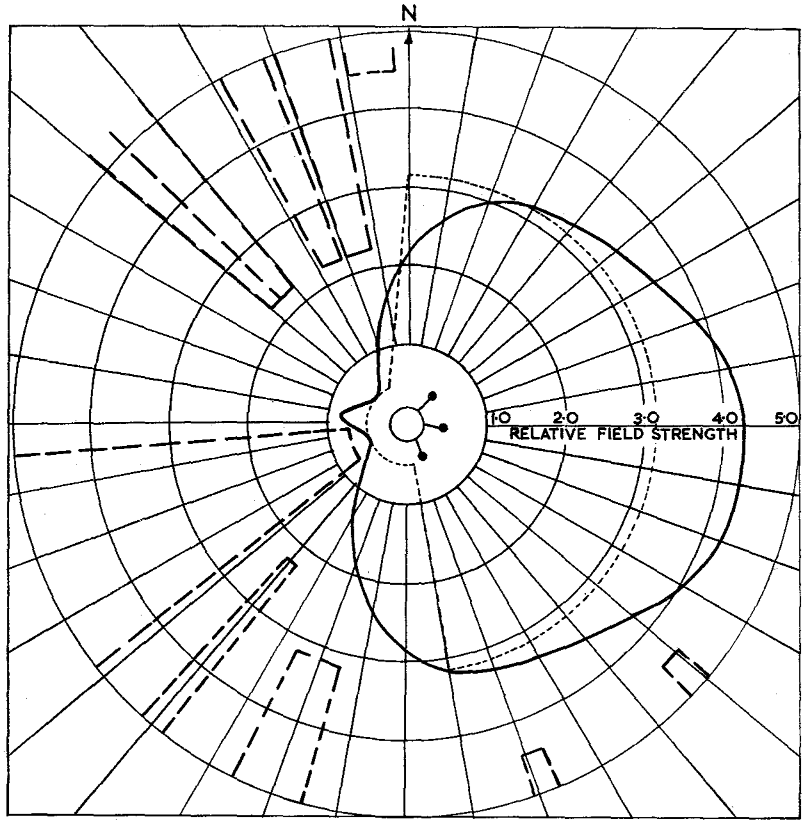

Fig. 4 - Measured horizontal radiation pattern of Band I aerial

Channel 1
Vertical polarization
Mean effective gain: 5·5 dB
Transmitter power: 4 × 0·5 kW
Mean e.r.p.: 7·1 kW

Vision and sound carrier offsets: +16·875 kc/s
▬ ▬ Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 1 kW

From the four h.r.p.s corresponding to conditions (a) and (b) the deviations of the e.r.p. from that obtaining with the correct current ratio were derived. From these deviations of e.r.p. it was possible to estimate:

(i) the minimum change in amplitude ratio which would result in a deviation of 1 dB from the correct h.r.p. at any bearing;

(ii) the minimum change in relative phase which would result in a deviation of 1 dB at any bearing.

The radiating current ratios corresponding to these deviations of the e.r.p. were joined by a smooth curve on a polar diagram shown in Fig. 5; provided that the measured complex current ratio is within the closed curve, the e.r.p. will be within 1 dB of the correct e.r.p.

A curve was also drawn for the tolerance in the current ratio at a frequency 3 Mc/s below that of the vision carrier. This was estimated in a similar manner but

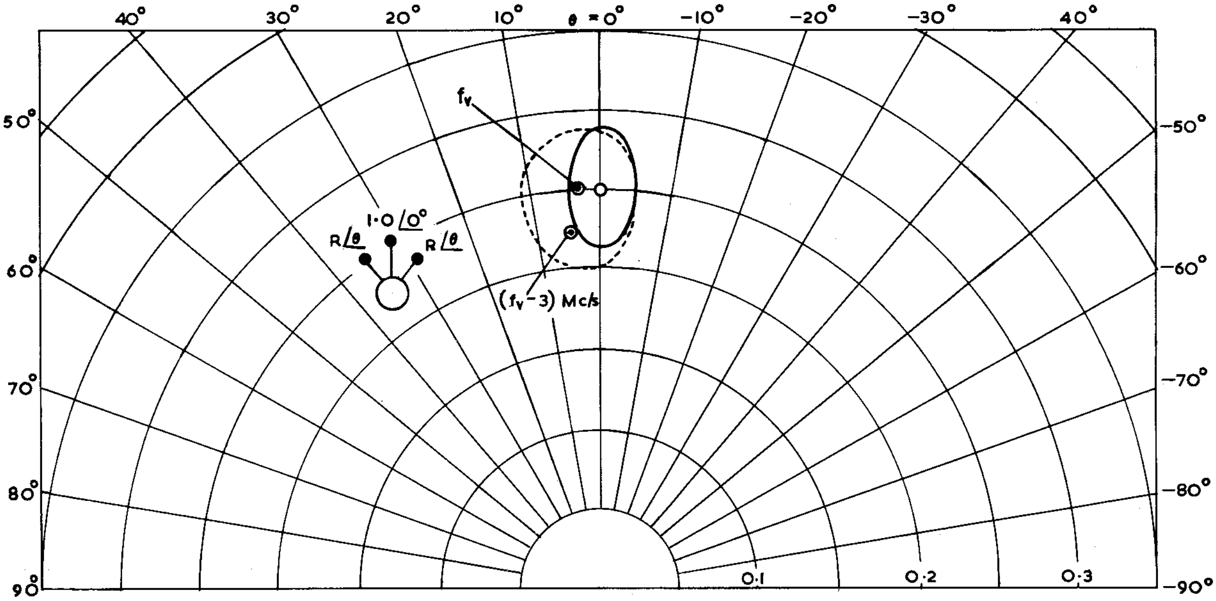

Fig. 5 - Current-ratio tolerance diagram

Vision carrier, f_v
f_v - 3 Mc/s
Measured aggregate current ratios on full-scale aerial

allowance was made for the inherent change of h.r.p. described in Section 3.1. The curve was drawn for a ± 2 dB variation in h.r.p., corresponding with an overall variation of ± 3 dB in e.r.p. over the video band at any bearing.

Fig. 5 shows the current-ratio tolerance curves, and the effective ratios achieved on one half of the full-scale aerial. The radiating current of each dipole was measured by small pick-up loops mounted on the dipole limbs near to the drive point. The points plotted in Fig. 5 show that the aggregate* current ratios are within the permitted tolerance.

3.3. Band II Aerial

The h.r.p. of the Band II aerial was required to satisfy the templet shown in Fig. 6. As in the case of Band I, the form of the aerial was based initially on a h.r.p. derived from tables of complex h.r.p.s of dipoles mounted on a cylinder. It was found that a theoretical h.r.p. satisfying the templet could be obtained with a tier of four tangential dipoles equally spaced round the mast, and fed with co-phased currents in the ratio of 2·0 : 1·0 : 1·0 : 1·0. This theoretical h.r.p., shown in Fig. 7, is, however, subject to the following approximations:

(a) In the calculation of the complex h.r.p. of a simple dipole on a cylinder, the component of field re-radiated by the cylinder is assessed by postulating a doublet in place of the dipole.

* The aggregate current is the vector sum of the radiating currents on one bearing. Thus the h.r.p. is that of an equivalent single tier consisting of three dipoles on bearings 38°, 98° and 158° ETN, the currents in which correspond to the aggregate currents of the four-tier aerial.

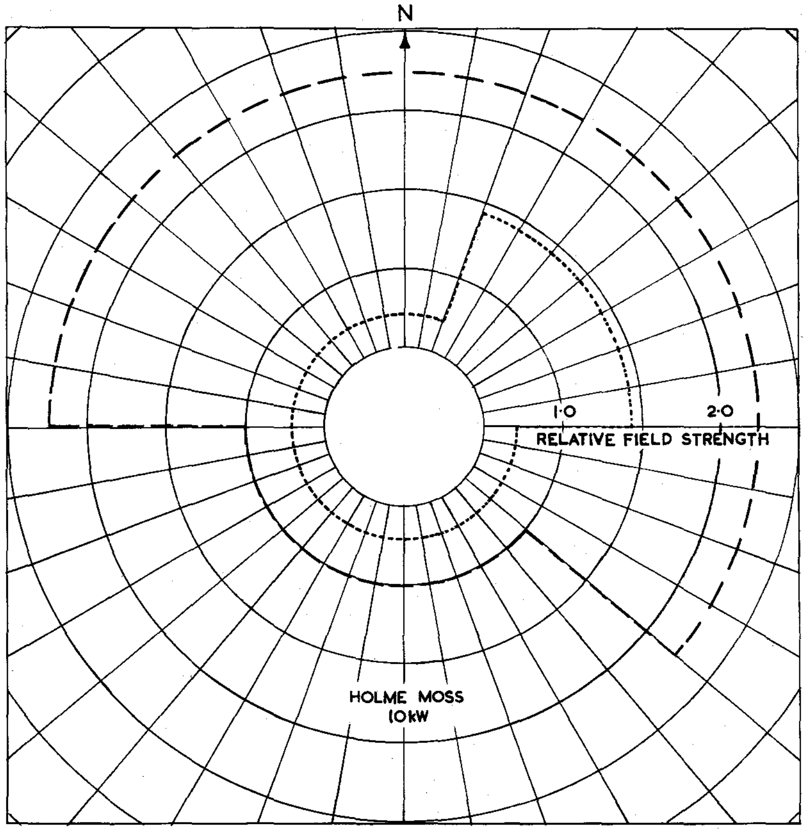

Fig. 6 - Templet for Band II aerial

Light: 89·1 Mc/s
Third: 91·3 Mc/s
Scottish Home: 93·5 Mc/s
— — Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 10 kW

(b) In calculating the composite h.r.p. of the system of four dipoles the effect of possible re-radiation from the support booms is neglected.

It was therefore necessary to carry out model measurements on a representative part of the aerial.

A model of one tier was constructed with a scale factor of 10·4 : 1 (corresponding with an operating frequency of 950 Mc/s). The dipoles were exact replicas of the full-scale design prepared by the aerial contractors, to ensure that re-radiation effects would be simulated accurately. Fig. 8(a) shows the basic features of the model dipole.

A double quarter-wave transformer, shown in Fig. 8(b), was used to establish the required dipole currents. To obtain co-phased radiating currents which are independent of dipole impedance, the total length of feeder between the dipole drive points and the common point of the transformer was made an odd number of quarter-wavelengths.

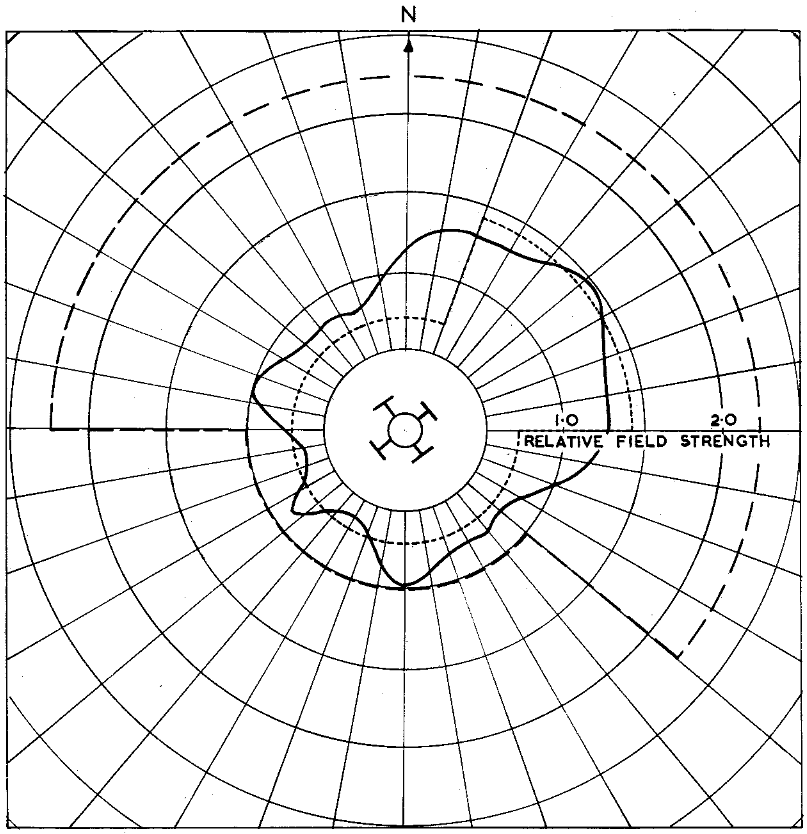

Fig. 7 - Theoretical horizontal radiation pattern of Band II aerial

Mean effective gain: 6·9 dB
Transmitter power: 2 × 1 kW
Mean e.r.p.: 9·8 kW
—— Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 10 kW

The radiating currents thus established were checked using an impedance perturbation method,[3] and were found at first to be insufficiently close to the required values. (This was presumably due to discontinuities at the dipole feed points and in the transformer.) After reducing the length of each distribution feeder by 0·035λ, currents within ± 2% in amplitude and ± 3° in phase of the required values were obtained. The measured h.r.p. of the aerial differed from the theoretical h.r.p. shown in Fig. 7 with the result that the radiated field in the north-westerly and south-easterly directions was lower than the templet requirements. However, by adjusting the spacing of the dipole at 53° ETN an h.r.p. having an acceptable fit to the templet was obtained. The full-scale spacing was reduced from 6 ft (1·83 m) to 5 ft 9½ in (1·76 m) and the resulting measured h.r.p. is shown in Fig. 9.

3.4. H.R.P. of Full-Scale Aerial

Since the Band II aerial has elements at four bearings, three radiating current ratios must be measured to assess the h.r.p. of the full-scale aerial. Although, on grounds of symmetry, the elements at 143° and 323° ETN can be presumed to carry equal currents, it is still difficult to use the method described in section

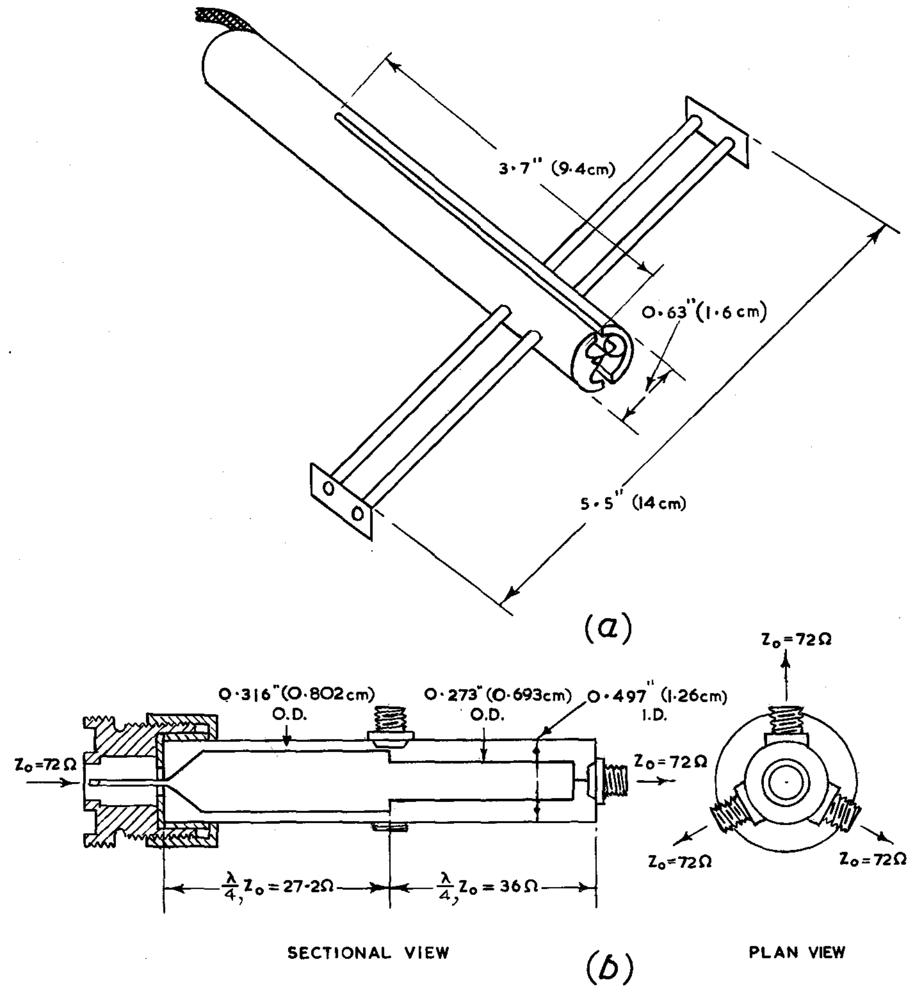

Fig. 8 - (a) Model Band II dipole
(b) Double quarter wave transformer

3.2. to specify the required accuracy of dipole currents, since two current ratios are then involved. It was therefore decided that the acceptance tests of the aerial (in respect of the h.r.p.) should be made by measuring the radiating currents and computing the h.r.p. that would result. Accordingly, this procedure was adopted, and the aerial currents adjusted to obtain a h.r.p. which did not deviate by more than 1 dB from that given in Fig. 7 at each of the three carrier frequencies.

4. GAIN

4.1. Band I Aerial

The mean intrinsic gain of the aerial was calculated using tables of mutual resistance between elements mounted on a cylinder.[4] This calculation does not

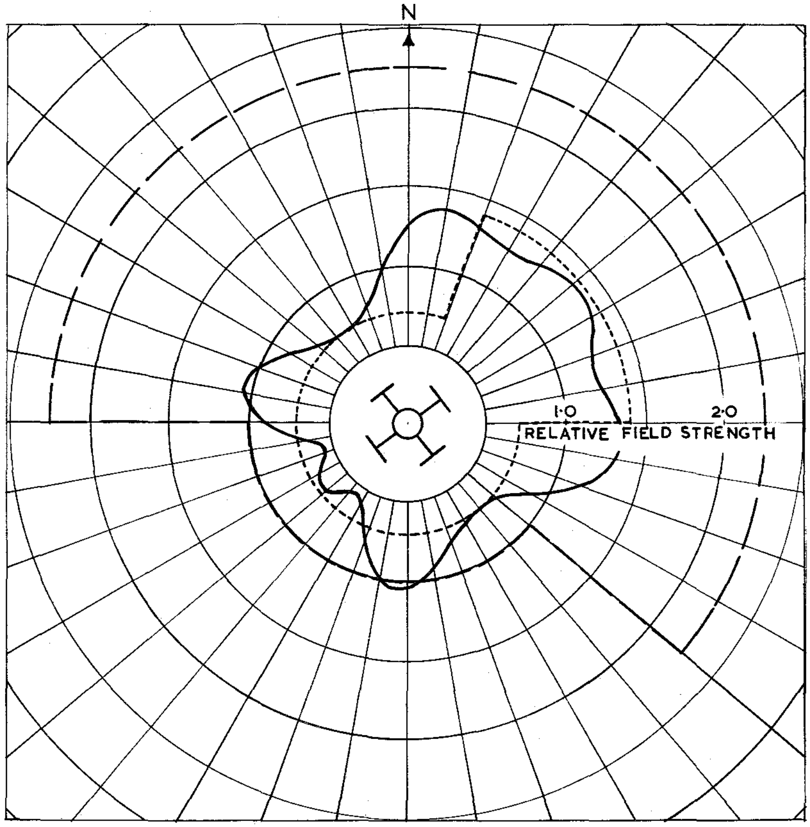

Fig. 9 - Measured horizontal radiation pattern of Band II aerial

Horizontal polarization
Mean effective gain: 6·9 dB
Transmitter power: 2 × 1 kW
Mean e.r.p.: 9·8 kW
——— Maximum permissible e.r.p.
------ Minimum desirable e.r.p.
Unit field corresponds to an e.r.p. of 10 kW

include the effect of stay wires on the aerial performance, but it is considered that any consequent change to the mean gain of the aerial would be very small. The mean effective gain was evaluated as follows:

Mean intrinsic gain			8·3 dB
Deduct:	loss due to gapfilling* and possible misalignment	0·5 dB	
	loss in distribution feeder	0·5 dB	1·0 dB
Mean net gain			7·3 dB
Deduct:	loss in main feeder	1·3 dB	
	network loss	0·5 dB	1·8 dB
Mean effective gain			5·5 dB

* See Section 5

4.2. Band II Aerial

The mean intrinsic gain was calculated using tables of mutual resistance between elements mounted on a cylinder. In this case the two following approximations were involved:

(a) The mutual resistance values were computed for doublet elements, whereas the aerial is comprised of $\lambda/2$ dipoles.

(b) The dipoles at bearing 53° ETN were assumed to be at the same spacing from the mast axis as dipoles on the other bearings.

The error resulting from these approximations is estimated to be small.

The mean effective gain was evaluated as follows:

Mean intrinsic gain			10·1 dB
Deduct:	loss due to possible misalignment	0·3 dB	
	loss in distribution feeder	0·5 dB	0·8 dB
Mean net gain			9·3 dB
Deduct:	loss in main feeder	1·5 dB	
	network loss	0·9 dB	2·4 dB
Mean effective gain			6·9 dB

5. GAPFILLING

If all the tiers were fed with equal co-phased currents the Band I aerial would have a zero in the vertical radiation pattern (v.r.p.) at an angle of 5·2° from the horizontal. The aerial height and ground profile place the corresponding outermost field strength minimum at a range of 2·4 miles (3·9 km), i.e. in the nearer outskirts of Selkirk. Consequently there was a risk that distorted signals might be received in this area, unless gapfilling measures were incorporated in the aerial.

It was therefore decided that this zero in the v.r.p. should be 'filled' by feeding dissimilar powers to the aerial halves. This is conveniently arranged in practice by feeding three of the four 500 W amplifiers comprising the transmitter installation into the upper half-aerial, and the remaining amplifier into the lower half-aerial. As a result, the radiated field in the direction of the outermost minimum is 20% of that of the main lobe maximum; the resulting reduction in aerial gain is 0·3 dB.

6. CONCLUSIONS

The aerials described in this report were initially designed theoretically to give horizontal radiation patterns conforming to the relevant templets. Minor

modifications were made as a result of experiment, and a performance which substantially meets the templet requirements was finally obtained. The technique adopted in the development of aerials of this type is therefore regarded as satisfactory.

7. REFERENCES

1. 'An Analogue Computer for Aerial Radiation Patterns', Research Department Report No. G-079, Serial No. 1960/23.

2. 'Tables of Horizontal Radiation Patterns of Dipoles Mounted on a Cylinder', Research Department Report No. E-071, Serial No. 1960/13.

3. Research Department report in course of preparation.

4. Research Department report in course of preparation.

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